

Title

Air Spring Elliptical Piston

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Reference to Related Applications

This application claims priority from U.S. provisional application serial number 60/412,472 filed September 20, 2002.

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Field of the Invention

The invention relates to an air spring and more particularly, to an air spring having a piston with an elliptical outer surface to cause a uniform stress distribution in an air spring sleeve.

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Background of the Invention

Compression and extension of a rolling lobe air spring causes fatiguing damage to the air spring sleeve. The damage accumulates over the life of the air spring until 20 failure of the sleeve occurs. The distribution of stress in the sleeve is an important factor in the durability of the sleeve. When the stress is uniform around the circumference of the sleeve in the rolling lobe, the durability is maximized.

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Side load compensating air springs utilize tilting the end cap of the air spring with respect to the axis of the piston/strut. This causes the stress distribution of the sleeve to become elliptical. This is a non-uniform stress distribution in comparison to the uniform stress 30 distribution. More particularly, a stress along the x axis of the spring is different than a stress in the y axis. Further, greater end cap tilt angles for greater side load

compensation result in higher non-uniform stress distribution and lower durability.

The durability of the air spring sleeve is reduced by the elliptical or non-uniform stress distribution. The more 5 non-uniform the stress distribution, the more durability is reduced.

Representative of the art is U.S. patent no. 5752692 (1998) to Crabtree et al. which discloses a chamber portion attached to a tilted closure and a rolling lobe portion of 10 an airsleeve attached to a piston that is transversely mounted.

The prior art air spring causes an elliptical, non-uniform stress distribution in the sleeve which shortens an operating life.

15 What is needed is a side-load compensating air spring piston having an elliptical cross-section. What is needed is a side-load compensating air spring having a sleeve with a substantially uniform stress distribution in a rolling lobe. The present invention meets this need.

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#### Summary of the Invention

The primary aspect of the invention is to provide a side-load compensating air spring piston having an elliptical cross-section.

25 Another aspect of the invention is to provide a side-load compensating air spring having a sleeve with a substantially uniform stress distribution in a rolling lobe.

Other aspects of the invention will be pointed out or 30 made obvious by the following description of the invention and the accompanying drawings.

The invention comprises a side load compensating air spring piston having an elliptical cross-section. The side load compensating air spring comprises an air spring sleeve forming a chamber and having a rolling lobe. One end of 5 the sleeve is attached to a tilted end cap for side load compensation. The other end of the sleeve has a rolling lobe engaged with a piston elliptical outer surface. The piston elliptical outer surface is disposed at a 90° angle to an elliptical stress distribution in the sleeve, thereby 10 rendering the stress distribution uniform in the sleeve rolling lobe portion as it rolls on the piston.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in 15 and form a part of the specification, illustrate preferred embodiments of the present invention, and together with a description, serve to explain the principles of the invention.

Fig. 1a is a cross-sectional view of a prior art air 20 spring.

Fig. 1b is a plan view of a prior art piston cross-section.

Fig. 1c is a plan view of a prior art air spring sleeve stress distribution.

25 Fig. 2a is a cross-sectional view of an inventive piston.

Fig. 2b is a plan view of an inventive piston cross-section B-B, and sleeve uniform stress distribution.

30 Fig. 2c is a plan view of a sleeve elliptical stress distribution.

Detailed Description of the Preferred Embodiment

Fig. 1a is a cross-sectional view of a prior art air spring. Air spring 100 comprises flexible sleeve 10. Sleeve 10 is air tight and forms a chamber that is attached 5 at one end to a tilted end cap 11. Sleeve 10 is attached to the end cap by crimp ring 110 or other suitable means known in the art. End cap 11 is round in plan. End cap 11 is tilted by angle  $\theta$  to compensate for a side load imposed upon the air spring. Angle  $\theta$  is the angle between an end 10 cap plane and a normal to a piston major axis A-A. Fasteners 12, such as threaded screws, attach the air spring to a mounting bracket (not shown). Sleeve 10 is constructed of elastomeric materials and in a manner known in the art. Sleeve 10 also comprises cords wound helically 15 within the elastomeric material. A helix angle of the helically wound cord need not be limited to a particular range in order to achieve the benefits of the instant invention.

The other end 13 of the sleeve 10 is attached to a 20 piston 20. Sleeve 10 is attached to the piston by crimp ring or other suitable means known in the art. As piston 20 compresses and rebounds, sleeve 10 forms a rolling lobe 15 on an outer surface 16 of piston 20. Rolling lobe 15 rolls along a length of outer surface 16 of piston 20 25 during operation of the air spring.

Fig. 1b is a plan view of a prior art piston cross-section. Outer surface 16 has a circular cross-section. Since end cap 11 is tilted and therefore not parallel to a piston plane that is normal to a major axis, sleeve 10 has 30 a substantially elliptical stress distribution 17. The elliptical stress distribution can manifest as wrinkles

appearing on the sleeve during compression strokes which reduce an operating life.

Fig. 1c is a plan view of a prior art air spring sleeve stress distribution.

5 Fig. 2a is a cross-sectional view of an inventive piston. Piston 140 comprises outer surface 160. The other components are as described in Fig. 1a. Outer surface 160 describes a substantially elliptical shape when viewed along an axis A-A. Outer surface 160 may be an integral  
10 part of piston 140. Outer surface 160 may also comprise an outer shroud 161 that is attached to piston 140. Fig. 2a depicts an outer shroud 161 having an elliptical outer surface 160.

Sleeve 10 has an elliptical stress distribution due to  
15 the tilted end cap 11 as described elsewhere herein. Fig. 2c is a plan view of a sleeve elliptical stress distribution. The sleeve elliptical stress distribution has a major axis on the y-axis and a minor axis on the x-axis.

20 Fig. 2b is a plan view of an inventive piston cross-section B-B, and sleeve uniform stress distribution. The elliptical cross-section of outer surface 160 is rotated approximately 90° to the orientation of the elliptical stress distribution in the sleeve. Namely, the outer  
25 surface 160 has a major axis on the x-axis and the minor axis on the y-axis. As rolling lobe 15 is formed upon and rolls on outer surface 160, the elliptical stress distribution in sleeve 10 becomes substantially uniform or in the instant case, substantially circular 170. The  
30 uniform substantially circular stress distribution 170 in sleeve 10 significantly increases the durability of the

sleeve. One can appreciate that the stress distribution may have a form other than circular and yet remain uniform.

A ratio between the major axis length and the minor axis length of outer surface 160 is selected in order to 5 establish a substantially uniform, or in the instant example circular, stress distribution in sleeve 10. The ratio of the lengths of the major axis and minor axis is dependent upon the degree of side load compensation, namely end cap tilt  $\theta$ . In a non-side load compensated air spring, 10 a tilt angle  $\theta$  of the end cap is zero and the ratio is 1.0 - a circle. In the case of a side-load compensating air spring having an end cap tilt angle of approximately 12 degrees, the ratio is approximately 1.2.

By way of example and not of limitation, in a test a 15 side-load compensating air spring sleeve was tested on an elliptical air spring piston having a ratio of approximately 1.08. The operating life of the tested sleeve was approximately five (5) times longer than the operating life of an identical sleeve mounted on a piston 20 having a circular cross section. In this example, the end cap tilt angle  $\theta$  was approximately seven (7) degrees.

Ratios for the inventive air spring piston are in the range of approximately 1.0 to 1.5 for end cap tilt angles  $\theta$  25 in a range of approximately  $0^\circ$  to  $20^\circ$ . One can appreciate that the relationship between the ratio and the end cap tilt is not in all cases linear.

Although a single form of the invention has been described herein, it will be obvious to those skilled in the art that variations may be made in the construction and 30 relation of parts without departing from the spirit and scope of the invention described herein.